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- (54) **ROTATIONAL SUPPORT FOR AN ELONGATE MEMBER**
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(52) **U.S. Cl.**

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(57)

ABSTRACT

Various exemplary drive apparatuses and associated methods are disclosed for driving an elongated member, e.g., a guidewire or catheter. An exemplary drive apparatus for driving an elongated member may include a rotational component configured to apply a torque to the elongated member, where the rotational component is positioned a first distance away from an insertion site along the elongated member. The drive apparatus may further include a rotational support configured to apply an assistance torque to the elongated member. The rotational support may be positioned a second distance from the rotational component along the elongated member that is larger than the first distance.

(58) **Field of Classification Search**

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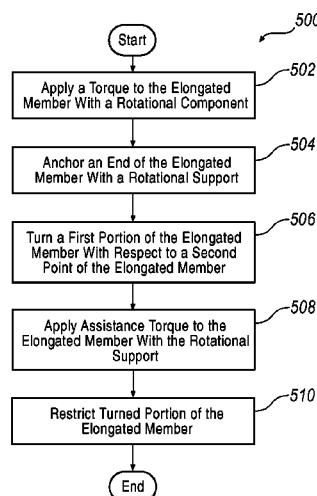
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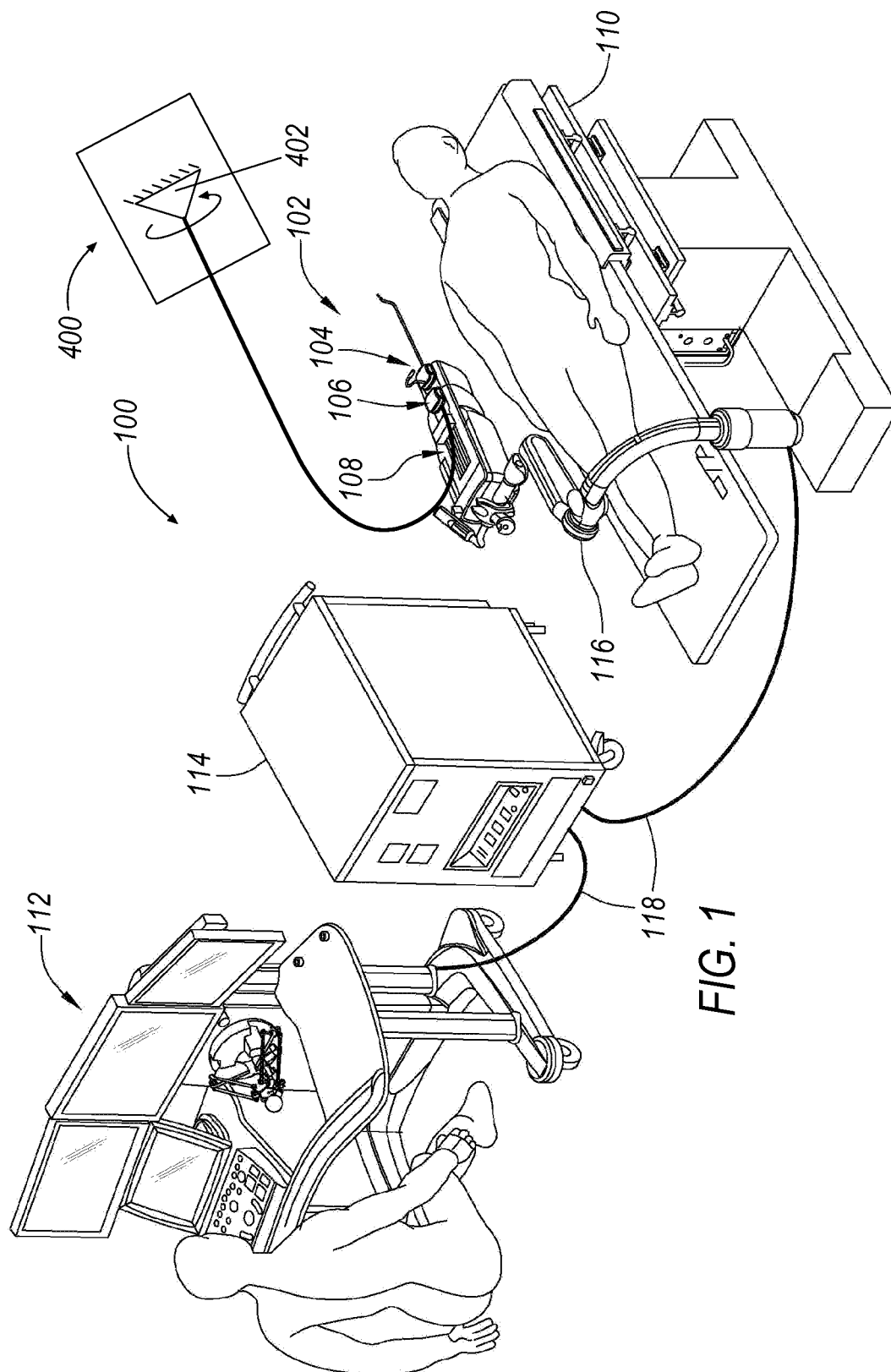
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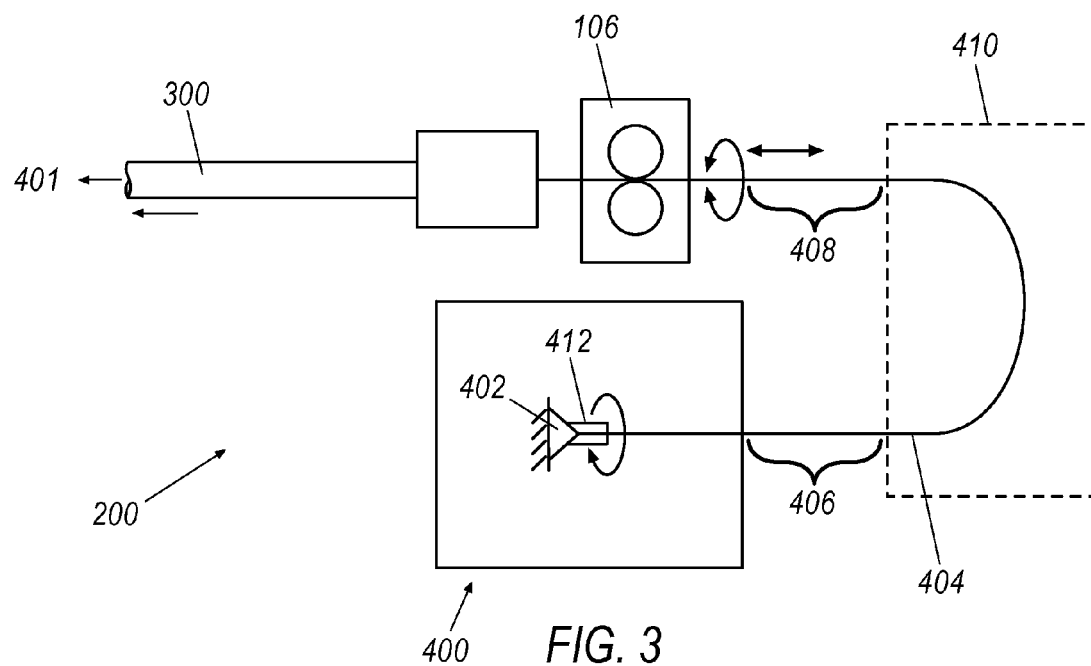
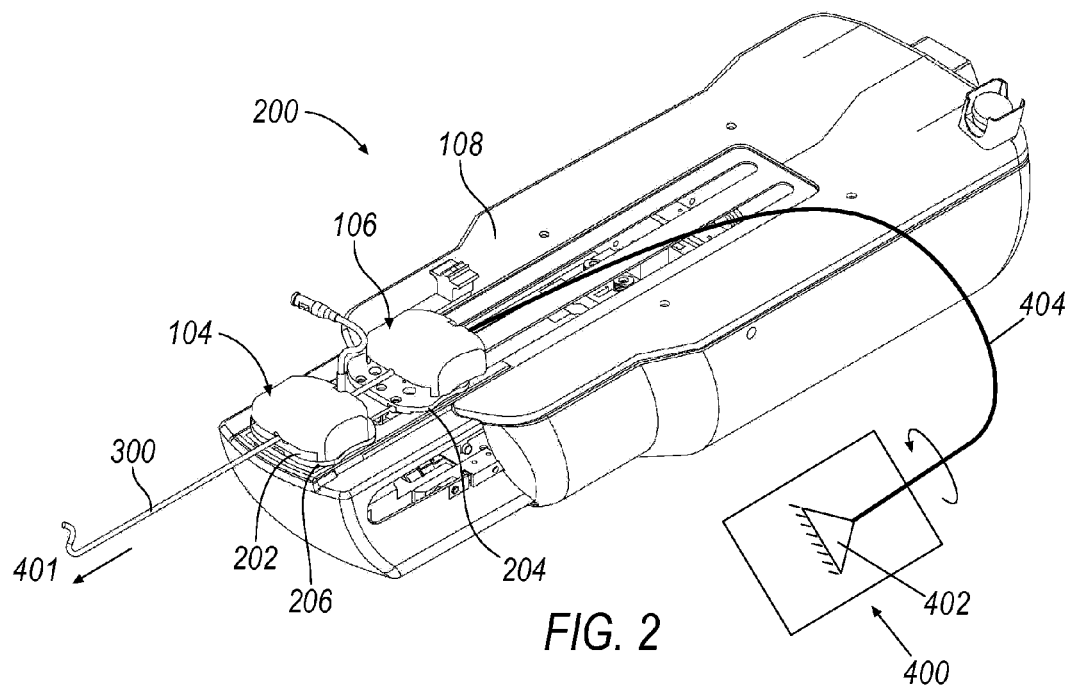
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18 Claims, 3 Drawing Sheets







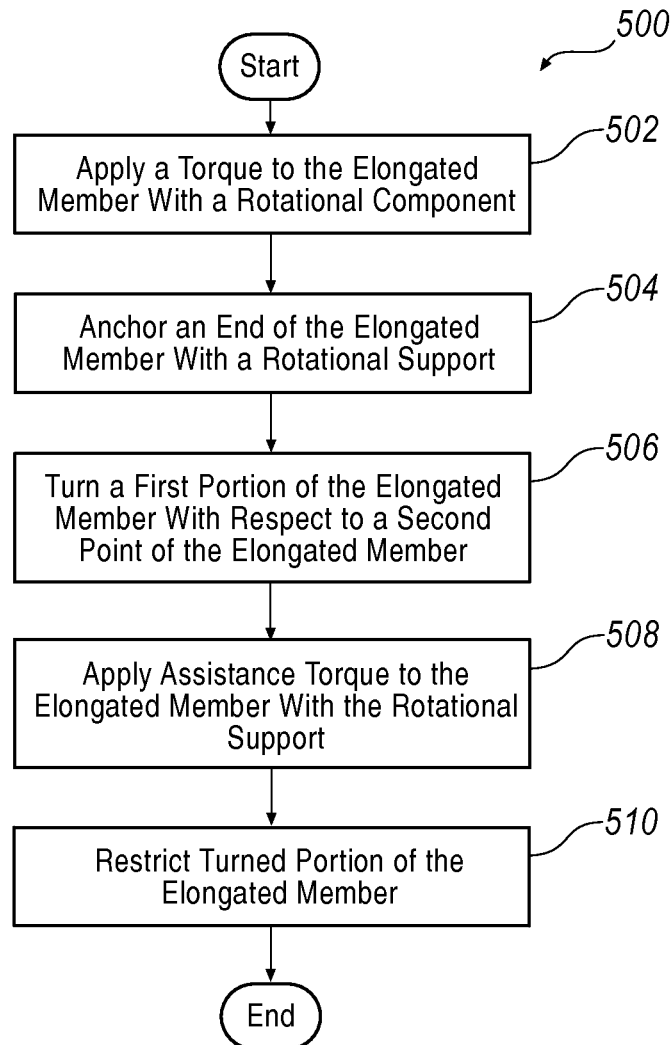


FIG. 4

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ROTATIONAL SUPPORT FOR AN ELONGATE MEMBER

BACKGROUND

Robotic interventional systems and devices are well suited for performing minimally invasive medical procedures as opposed to conventional techniques wherein the patient's body cavity is open to permit the surgeon's hands access to internal organs. However, advances in technology have led to significant changes in the field of medical surgery such that less invasive surgical procedures, in particular, minimally invasive surgery (MIS), are increasingly popular.

A MIS is generally defined as a procedure that is performed by entering the body through the skin, a body cavity, or an anatomical opening utilizing small incisions rather than large, open incisions in the body. With MIS, it is possible to achieve less operative trauma for the patient, reduced hospitalization time, less pain and scarring, reduced incidence of complications related to surgical trauma, lower costs, and a speedier recovery.

Special medical equipment may be used to perform MIS procedures. Typically, a surgeon inserts small tubes or ports into a patient and uses endoscopes or laparoscopes having a fiber optic camera, light source, or miniaturized surgical instruments.

MIS apparatus and techniques have advanced to the point where an insertion and rolling motion of components of an elongated component such as a catheter instrument, e.g., a catheter sheath and associated guidewire, are generally controllable by selectively operating rollers or other mechanisms for generally gripping the component. Due to the length and complexity of catheter instruments and components thereof, rotation of the catheter may be generally difficult to control.

Accordingly, there is a need in the art for systems and methods for inserting and rolling catheter components that address or solve the above problems.

SUMMARY

An exemplary method of driving an elongated member, e.g., a guidewire or catheter, merely as examples, may include applying a first torque to the elongated member with a rotational component that is positioned a first distance away from an insertion site along the elongated member. The exemplary method may further include applying an assistance torque to the elongated member with a rotational support positioned a second distance away from an insertion site along the elongated member, where the second distance is larger than the first distance.

An exemplary drive apparatus for driving an elongated member may include a rotational component configured to apply a torque to the elongated member, where the rotational component is positioned a first distance away from an insertion site along the elongated member. The drive apparatus may further include a rotational support configured to apply an assistance torque to the elongated member. The rotational support may be positioned a second distance from the rotational component along the elongated member that is larger than the first distance.

BRIEF DESCRIPTION OF THE DRAWINGS

While the claims are not limited to the illustrated embodiments, an appreciation of various aspects is best gained

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through a discussion of various examples thereof. Referring now to the drawings, illustrative embodiments are shown in detail. Although the drawings represent the embodiments, the drawings are not necessarily to scale and certain features may be exaggerated to better illustrate and explain an innovative aspect of an embodiment. Further, the embodiments described herein are not intended to be exhaustive or otherwise limiting or restricting to the precise form and configuration shown in the drawings and disclosed in the following detailed description. Exemplary embodiments of the present invention are described in detail by referring to the drawings as follows.

FIG. 1 is an illustration of a robotically controlled surgical system, according to one exemplary illustration;

FIG. 2 is an illustration of an exemplary catheter assembly of the surgical system of FIG. 1;

FIG. 3 is a schematic view of the exemplary illustration of an exemplary catheter assembly of the surgical system of FIGS. 1 and 2; and

FIG. 4 is process flow diagram for an exemplary method of driving an elongated member.

DETAILED DESCRIPTION

Referring now to the drawings, illustrative embodiments are shown in detail. Although the drawings represent the embodiments, the drawings are not necessarily to scale and certain features may be exaggerated to better illustrate and explain an innovative aspect of an embodiment. Further, the embodiments described herein are not intended to be exhaustive or otherwise limit or restrict the invention to the precise form and configuration shown in the drawings and disclosed in the following detailed description.

Referring to FIG. 1, a robotically controlled surgical system **100** is illustrated in which an apparatus, a system, and/or method may be implemented according to various exemplary illustrations. System **100** may include a robotic catheter assembly **102** having a robotic or first or outer steerable complement, otherwise referred to as a sheath instrument **104** (generally referred to as "sheath" or "sheath instrument") and/or a second or inner steerable component, otherwise referred to as a robotic catheter or guide or catheter instrument **106** (generally referred to as "catheter" or "catheter instrument"). Catheter assembly **102** is controllable using a robotic instrument driver **108** (generally referred to as "instrument driver").

Moreover, as described further below in regard to FIGS. 2 and 3, a rotational support **400** may be provided which is configured to provide an assistance torque to an elongate member that is part of the catheter assembly **102**. For example, a rotational support **400** may be configured to provide an assistance torque to a guidewire inserted coaxially into the catheter **102** assembly, e.g., within a catheter sheath. The rotational support **400** may be used to support an elongated member such as the guidewire rotationally, to allow a greater degree of control over the rotation of the elongate member.

During use, a patient is positioned on an operating table or surgical bed **110** (generally referred to as "operating table") to which robotic instrument driver **108** may be coupled or mounted. In the illustrated example, system **100** includes an operator workstation **112**, an electronics rack **114** and associated bedside electronics box (not shown), a setup joint mounting brace **116**, and instrument driver **108**. A surgeon is seated at operator workstation **112** and can monitor the surgical procedure, patient vitals, and control one or more catheter devices. Operator workstation **112** may

include a computer monitor to display a three dimensional object, such as a catheter instrument or component thereof, e.g., a guidewire, catheter sheath. Moreover, a catheter instrument may be displayed within or relative to a three dimensional space, such as a body cavity or organ, e.g., a chamber of a patient's heart. In one example, an operator uses a computer mouse to move a control point around the display to control the position of catheter instrument.

System components may be coupled together via a plurality of cables or other suitable connectors **118** to provide for data communication, or one or more components may be equipped with wireless communication components to reduce or eliminate cables **118**. Communication between components may also be implemented over a network or over the internet. In this manner, a surgeon or other operator may control a surgical instrument while being located away from or remotely from radiation sources, thereby decreasing radiation exposure. Because of the option for wireless or networked operation, the surgeon may even be located remotely from the patient in a different room or building.

Referring now to FIG. 2, an exemplary drive assembly **200** is shown in further detail, including sheath instrument **104** and the associated guide or catheter instrument **106** mounted to mounting plates **202**, **204** on a top portion of instrument driver **108**. During use, catheter instrument **106** is inserted within a central lumen of sheath instrument **104** such that instruments **104**, **106** are arranged in a coaxial manner. Although instruments **104**, **106** are arranged coaxially, movement of each instrument **104**, **106** can be controlled and manipulated independently. For this purpose, motors within instrument driver **108** are controlled such that carriages coupled to each of the instruments **104**, **160** may allow the instruments **104**, **106** to be driven forwards and backwards along the driver **108**, e.g., with mounting plates securing the instruments to the driver **108** on bearings. As a result, a catheter **300** coupled to guide catheter instrument **106** and sheath instrument **104** can be controllably manipulated while inserted into the patient, as will be further illustrated. Additional instrument driver **108** motors (not shown in FIG. 2) may be activated to control bending of the catheter as well as the orientation of the distal tips thereof, including tools mounted at the distal tip. Sheath catheter instrument **106** is configured to move forward and backward for effecting an axial motion of the catheter, e.g., to insert and withdraw the catheter from a patient, respectively. For example, the catheter **300** is configured to be inserted and removed from the patient's body at an insertion site **401**.

At least one of the instruments **104**, **106** may apply a torque to an elongated member included in the catheter **300**. For example, a guidewire **404** may be inserted into the instruments **104**, **106** for guiding the catheter **300**. In one exemplary illustration, the instrument **106** applies a torque to the guidewire **404**, e.g., to impart a rotational motion for guidance of the catheter. The rotational support **400**, which is positioned further away from the insertion site **401** than the instrument **106**, may apply an assistance torque to the guidewire **404**, and end of which is attached to the rotational support **400** at a fixture **402**. In some exemplary approaches described further below, the assistance torque may be a larger amount than that applied by the instrument **106**. In another example, the assistance torque is applied as a "coarse" adjustment relative to torque being applied by the instrument **106**, wherein torque is applied to the guidewire **404** in relatively large amounts via the rotational support **400**. By contrast, torque may be more finely adjusted by the instrument **106**. In this manner, the application of torque using the rotational support **400** and the instrument **106** is

similar to a physician using two hands to rotate the wire, where the hand closest to the operating/insertion site makes fine torque adjustments, perhaps with only the fingertips, while the rearward hand makes relatively larger "gross" torque adjustments with the hand grasping the wire. Moreover, the rotational support **400** may have a relatively tighter grip on the rearward end of the guidewire, as will be described further below.

Referring now to FIG. 3, the exemplary drive assembly **200** is illustrated in further detail. The rotational component or instrument **106**, as noted above, may be configured to apply a torque to the elongated member, e.g., a guidewire **404**, while the rotational support **400** is configured to apply an assistance torque to the elongated member. The guidewire **404** includes a turned portion **406** which is wrapped approximately 180 degrees with respect to another portion **408** that is aligned for insertion into the instrument **106**. The turning of the guidewire **404** may generally facilitate insertion of the guidewire **404**, i.e., by placing the end **408** of the guidewire **404** relatively close to the instrument **106**. Accordingly, during insertion of the guidewire **404** into the instrument **106**, the lengths of the turned portion **406** and the aligned portion may decrease as a greater length overall of the guidewire **404** is inserted. As a result of the turning of the wire, e.g., to the 180 degree orientation, the rotational support **400** does not require movement relative to the rotational component **106**. Alternatively, if the elongate member were oriented straight, i.e., such that the entire elongate member were aligned along the insertion axis of the instrument **106**, the rotational support **400** would be required to mount to a moveable carriage to allow insertion and retraction of the elongate member.

The turning of the guidewire **404** may also facilitate the use of an intermediate support **410** for the guidewire **404** in between the rotational support **400** and the instrument **106**. In particular, to the extent there is any difference in torque or rotational movement being applied to the guidewire **404** by the rotational support **400** on the one hand and the instrument **106** on the other, an intermediate support **410** may generally prevent the guidewire **404** from twisting. In one exemplary approach, the intermediate support **410** includes two planar members generally sandwiching the guidewire **404** therebetween. Accordingly, the guidewire **404** is generally forced to remain substantially in a single plane. Moreover, the use of two planar members may generally freely permit movement of the guidewire **404** as a result of insertion, i.e., taking up more of the slack in the guidewire. As another example, the guidewire **404** may be placed in a track (not shown). As yet another example, one or more weights (not shown) may be applied or secured to the guidewire **404**, e.g., along a length of the guidewire **404** intermediate the rotational support **400** and the instrument **106**, to inhibit vertical movement of the guidewire **404**, thereby preventing the guidewire **404** from twisting upon itself.

The rotational support **400** may generally anchor or fix the end to an infinitely rotatable support **402**. For example, the support **402** may be a collet comprising a sleeve **412** that extends from the end of the elongated member, i.e., the guidewire, along a length of the elongated member. The end of the guidewire **404** may thereby be generally anchored to the rotational support **400**. Moreover, the end of the guidewire may be generally gripped or anchored in a far more aggressive manner than generally possible for the instrument **106**, as the instrument **106** must generally be configured to apply fine torque adjustments to the guidewire **404**. Moreover, the instrument **106** must generally not damage the

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guidewire **406**. By contrast, the end of the guidewire **404** may be anchored or clamped within the rotational support **400** as aggressively as possible to maintain a relatively firm grip on the guidewire. The end of the guidewire **404** is generally permanently fixed to the rotational support **400**, and can be clamped aggressively, without any regard for damage to the guidewire **404** that the instrument **106**, on the other hand, must generally avoid. Moreover, in one exemplary illustration, the end of the guidewire **404** is grabbed by a disposable component through a sterile drape (not shown in FIG. 3), allowing the rotational support **400** to remain under the sterile drape. Accordingly, reuse of the rotational support **400** for subsequent procedures is generally possible.

In some exemplary approaches, as noted above the rotational support **400** may be configured to adjust the assistance torque in relatively large increments as a “gross” adjustment, while the rotational component, i.e., instrument **106**, is configured to apply torque adjustments in smaller increments as a “fine” adjustment. Moreover, the rotational support **400** may include any rotational device that is convenient, e.g., an infinitely rotatable tool such as a geared wheel (not shown) or other mechanism configured to rotate continuously. Accordingly, the rotational support **400** need not be limited to any particular rotational range of motion. Moreover, the use of an infinitely rotatable tool also facilitates the generally permanent clamping of the end of the guidewire **404**, since there is no need to release and re-grip the guidewire **404**.

In another exemplary illustration, the rotational support **400** may be used to apply a proportionally greater rotational movement or torque to an elongate member, e.g., guidewire **404**. In some exemplary approaches, the rotational component, i.e., instrument **106**, may generally be used to selectively release the guidewire **404** after the application of a relatively larger amount of rotation and/or torque that is needed in a given procedure. More specifically, the rotational support **400** may be used to “wind up” the guidewire to a magnitude, e.g., a torque, that generally exceeds a torque expected for a given procedure or movement of the elongate member. Subsequently, the instrument **106** may selectively “deploy” the torque present in the length of the elongate member between the instrument **106** and the rotational support **400** to the length of the elongate member in between the instrument **106** and an insertion site, e.g., insertion site **401**.

In another example, for each magnitude of rotation applied to the guidewire **404** by the instrument **106**, the rotational support **400** may rotate a larger magnitude. In one example, the rotational support **400** turns four times more than the corresponding instrument **106**. The particular relationship between the magnitude of the rotation of the rotation support **400** and the instrument **106** will be dependent on the wire length and type. For example, where a larger length of the elongated member, e.g., guidewire **400** is employed, the greater length may allow a larger difference in rotation between the rotational support **400** and the instrument **106**. Additionally, where a more delicate elongate member is employed, a comparatively smaller difference in rotation between the rotational support **400** and the instrument **106** may be employed in view of the increased likelihood of damaging the elongate member.

Referring now to FIG. 4, an exemplary process **400** of driving an elongated member is described. Process **400** may begin at block **402**, where a first torque is applied to an elongate member with a rotational component. For example, as described above a first torque may be applied to an elongate member, e.g., guidewire **404**, with a rotational

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component, e.g., instrument **106**. The instrument **106** may be positioned a first distance away from an insertion site along the elongated member, such that it is closer to the insertion site than an associated rotational support, e.g., rotational support **400**. Process **400** may then proceed to block **404**.

At block **404**, an end of the elongate member may be anchored with the rotational support. For example, an end of a guidewire **404** may be anchored to a collet **402** or within a sleeve **412** that is configured to secure the end of the guidewire **404**. Moreover, the elongate member may be generally deformed within the collet **402** or sleeve **412**, as the guidewire **400** need not be handled delicately since the end of the guidewire **404** adjacent the rotational support **400** and an adjacent length is not expected to be used for insertion or to be handled by the instrument **106**. As described above, the end of the elongate member, e.g., guidewire **404**, may be received within a sleeve **412** that extends along a length of the guidewire **404**, thereby facilitating a generally secure grip and allowing application of generally greater torque and/or rotational magnitude than is generally possible with the instrument **106**. Process **400** may then proceed to block **406**.

At block **406**, a first portion of the elongate member may be turned with respect to a second portion of the elongate member. For example, as described above a first portion **406** of a guidewire **404** may be turned such that it is rotated approximately 180 degrees with respect to a second portion **408** that is aligned for insertion into the rotational component, i.e., instrument **106**.

Proceeding to block **408**, an assistance torque or rotation may be applied to the elongate member with a rotational support, e.g., rotational support **400**. The rotational support **400**, in some examples as described above, may be positioned generally further away from an insertion site along the elongated member than the rotational component, i.e., the instrument **106**. In some exemplary approaches, the assistance torque and/or the rotational movement applied by the rotational support **400** may be greater than the torque and/or rotational movement applied by the rotational component, e.g., instrument **106**. In some examples, the rotational component, e.g., instrument **106**, may be used to selectively release a portion of the assistance torque being applied by the rotational support **400**. More specifically, the rotational support **400** may apply an assistance torque or rotational movement that is relatively larger than expected to be applied by the instrument **106**. The instrument **106** may then release a portion of the rotational movement and/or the torque to the portion of the elongate member between the instrument **106** and the insertion site. The assistance torque may function, in some examples, as a coarse torque adjustment with respect to a relatively fine torque adjustment applied by the rotational component, i.e., the instrument **106**. For example, the assistance torque may be adjusted or applied in larger increments than the torque applied by the rotational component, i.e., the instrument **106**. The rotational support **400** may also have a generally infinite rotational range of motion, e.g., with a generally circular wheel or other continuously rotatable tool, thereby permitting continuous rotational movement to be applied to any degree without requiring releasing or re-gripping the elongate member.

Proceeding to block **410**, a turned portion of the elongate member may be restricted, e.g., to inhibit or prevent twisting of the elongate member. For example, as described above a curved portion of the guidewire **404**, i.e., extending between a turned portion **406** and an aligned portion **408** of the guidewire may be kept substantially within a predetermined

plane. The restriction of the elongate member may be accomplished using corresponding planar members **410** that may be used to generally trap the elongate member, e.g., a guidewire, therebetween, thereby generally preventing movement of the elongate member outside of the plane defined between the two planar members. Moreover, movement of the guidewire **404** within the defined plane may generally be freely allowed, resulting in a minimal restriction on the guidewire **404** that does not overly interfere with the movement of the guidewire **404**, e.g., during insertion.

Operator workstation **112**, electronics rack **114**, drive apparatus **200**, and/or rotational support **400** may include a computer or a computer readable storage medium implementing the operation of drive and implementing the various methods and processes described herein, e.g., process **1300**. In general, computing systems and/or devices, such as the processor and the user input device, may employ any of a number of computer operating systems, including, but by no means limited to, versions and/or varieties of the Microsoft Windows® operating system, the Unix operating system (e.g., the Solaris® operating system distributed by Oracle Corporation of Redwood Shores, Calif.), the AIX UNIX operating system distributed by International Business Machines of Armonk, N.Y., the Linux operating system, the Mac OS X and iOS operating systems distributed by Apple Inc. of Cupertino, Calif., and the Android operating system developed by the Open Handset Alliance.

Computing devices generally include computer-executable instructions, where the instructions may be executable by one or more computing devices such as those listed above. Computer-executable instructions may be compiled or interpreted from computer programs created using a variety of programming languages and/or technologies, including, without limitation, and either alone or in combination, Java™, C, C++, Visual Basic, Java Script, Perl, etc. In general, a processor (e.g., a microprocessor) receives instructions, e.g., from a memory, a computer-readable medium, etc., and executes these instructions, thereby performing one or more processes, including one or more of the processes described herein. Such instructions and other data may be stored and transmitted using a variety of computer-readable media.

A computer-readable medium (also referred to as a processor-readable medium) includes any non-transitory (e.g., tangible) medium that participates in providing data (e.g., instructions) that may be read by a computer (e.g., by a processor of a computer). Such a medium may take many forms, including, but not limited to, non-volatile media and volatile media. Non-volatile media may include, for example, optical or magnetic disks and other persistent memory. Volatile media may include, for example, dynamic random access memory (DRAM), which typically constitutes a main memory. Such instructions may be transmitted by one or more transmission media, including coaxial cables, copper wire and fiber optics, including the wires that comprise a system bus coupled to a processor of a computer. Common forms of computer-readable media include, for example, a floppy disk, a flexible disk, hard disk, magnetic tape, any other magnetic medium, a CD-ROM, DVD, any other optical medium, punch cards, paper tape, any other physical medium with patterns of holes, a RAM, a PROM, an EPROM, a FLASH-EEPROM, any other memory chip or cartridge, or any other medium from which a computer can read.

Databases, data repositories or other data stores described herein may include various kinds of mechanisms for storing, accessing, and retrieving various kinds of data, including a

hierarchical database, a set of files in a file system, an application database in a proprietary format, a relational database management system (RDBMS), etc. Each such data store is generally included within a computing device employing a computer operating system such as one of those mentioned above, and are accessed via a network in any one or more of a variety of manners. A file system may be accessible from a computer operating system, and may include files stored in various formats. An RDBMS generally employs the Structured Query Language (SQL) in addition to a language for creating, storing, editing, and executing stored procedures, such as the PL/SQL language mentioned above.

In some examples, system elements may be implemented as computer-readable instructions (e.g., software) on one or more computing devices (e.g., servers, personal computers, etc.), stored on computer readable media associated therewith (e.g., disks, memories, etc.). A computer program product may comprise such instructions stored on computer readable media for carrying out the functions described herein.

The exemplary illustrations are not limited to the previously described examples. Rather, a plurality of variants and modifications are possible, which also make use of the ideas of the exemplary illustrations and therefore fall within the protective scope. Accordingly, it is to be understood that the above description is intended to be illustrative and not restrictive.

With regard to the processes, systems, methods, heuristics, etc. described herein, it should be understood that, although the steps of such processes, etc. have been described as occurring according to a certain ordered sequence, such processes could be practiced with the described steps performed in an order other than the order described herein. It further should be understood that certain steps could be performed simultaneously, that other steps could be added, or that certain steps described herein could be omitted. In other words, the descriptions of processes herein are provided for the purpose of illustrating certain embodiments, and should in no way be construed so as to limit the claimed invention.

Accordingly, it is to be understood that the above description is intended to be illustrative and not restrictive. Many embodiments and applications other than the examples provided would be upon reading the above description. The scope of the invention should be determined, not with reference to the above description, but should instead be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. It is anticipated and intended that future developments will occur in the arts discussed herein, and that the disclosed systems and methods will be incorporated into such future embodiments. In sum, it should be understood that the invention is capable of modification and variation and is limited only by the following claims.

All terms used in the claims are intended to be given their broadest reasonable constructions and their ordinary meanings as understood by those skilled in the art unless an explicit indication to the contrary is made herein. In particular, use of the singular articles such as “a,” “the,” “the,” etc. should be read to recite one or more of the indicated elements unless a claim recites an explicit limitation to the contrary.

The invention claimed is:

1. A method of driving an elongate member, the method comprising:

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applying a first torque to the elongate member with a rotational component positioned a first distance away from an insertion site along the elongate member; applying an assistance torque to the elongate member with a rotational support positioned a second distance away from the insertion site along the elongate member, the second distance being larger than the first distance; turning a first portion of the elongate member with respect to a second portion of the elongate member; and restricting the first portion of the elongate member within a predetermined plane.

2. The method of claim 1, wherein the assistance torque is greater than the first torque.

3. The method of claim 1, wherein the assistance torque is a coarse torque adjustment, and the first torque is a fine torque adjustment.

4. The method of claim 1, further comprising adjusting the assistance torque in a first increment, and adjusting the first torque in a second increment smaller than the first increment.

5. The method of claim 1, further comprising anchoring an end of the elongate member with the rotational support.

6. The method of claim 5, wherein anchoring the end of the elongate member includes deforming the elongate member adjacent the end.

7. The method of claim 1, further comprising receiving an end of the elongate member within a sleeve extending from the end of the elongate member along a length of the elongate member.

8. The method of claim 1, wherein the rotational support has an infinite rotational range of motion.

9. The method of claim 1, wherein the first portion of the elongate member is turned 180 degrees from the second portion.

10. The method of claim 1, wherein the elongate member is configured to define variable lengths of the elongate member between the rotational component and the rotational support without relative movement between the rotational component and rotational support.

11. The method of claim 1, wherein driving the elongate member comprises driving a guidewire.

12. The method of claim 1, further comprising selectively releasing a portion of the assistance torque with the rotational component.

13. A method of driving an elongate member, the method comprising:

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applying a first torque to the elongate member with a rotational component positioned a first distance away from an insertion site along the elongate member; turning a first portion of the elongate member with respect to a second portion of the elongate member, wherein the first portion of the elongate member is turned 180 degrees from the second portion of the elongate member;

anchoring an end of the elongate member with the rotational support; and

applying an assistance torque to the elongate member with a rotational support positioned a second distance away from an insertion site along the elongate member, the second distance being larger than the first distance.

14. The method of claim 13, wherein a portion of the elongate member is positioned intermediate the rotational component and the rotational support.

15. The method of claim 13, wherein the elongate member is a guidewire.

16. A drive apparatus for driving an elongate member, the drive apparatus comprising:

a rotational component configured to apply a torque to the elongate member, the rotational component positioned a first distance away from an insertion site along the elongate member; and

a rotational support configured to apply an assistance torque to the elongate member, the rotational support positioned a second distance from the insertion site along the elongate member, the second distance being larger than the first distance,

wherein the rotational support includes a sleeve anchoring an end of the elongate member, the sleeve extending from the end of the elongate member along a length of the elongate member.

17. The drive apparatus of claim 16, further comprising an intermediate support positioned intermediate the rotational component and the rotational support, the intermediate support configured to maintain a turned portion of the elongate member substantially in a single plane.

18. The drive apparatus of claim 16, wherein the rotational support is configured to adjust the assistance torque in a first increment, and the rotational component is configured to adjust the first torque in a second increment smaller than the first increment.

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